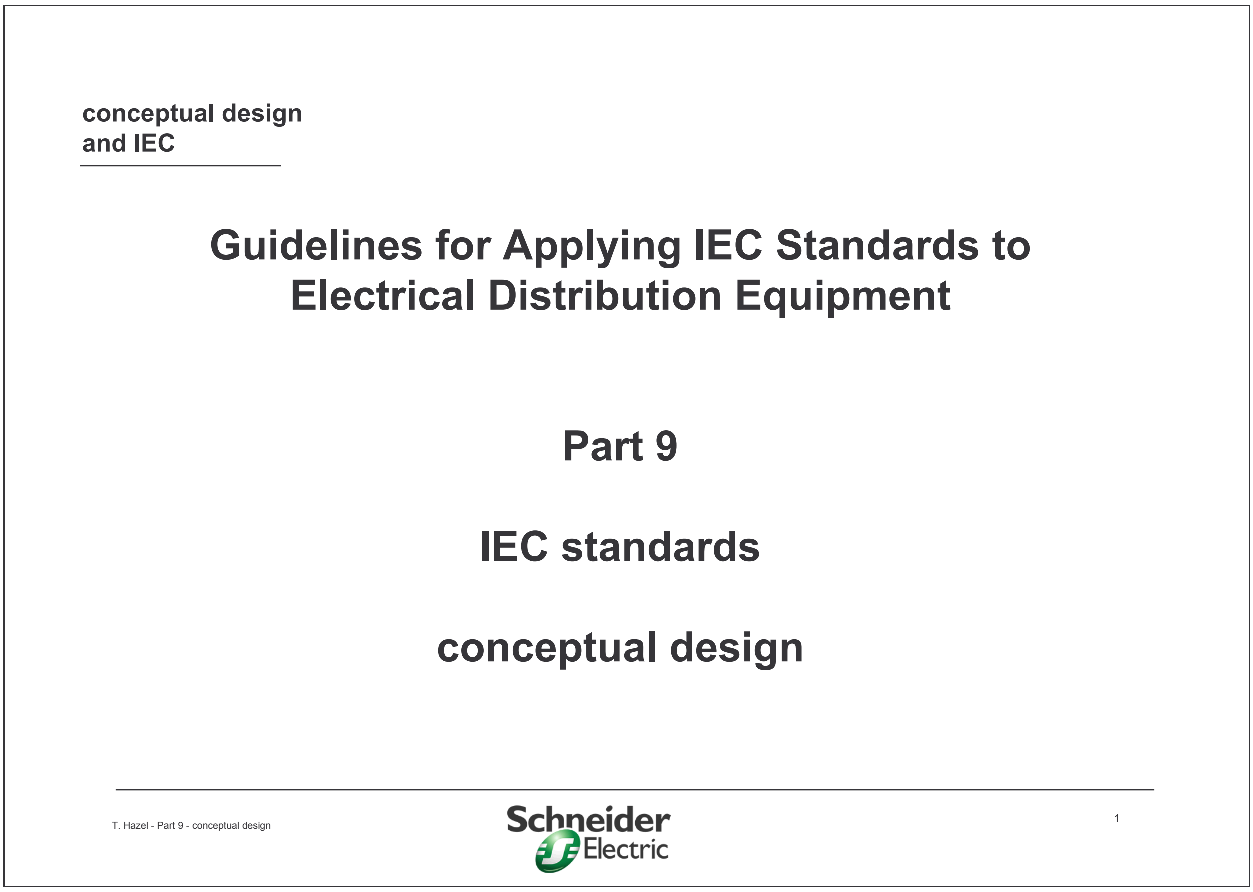


conceptual design
and IEC

Guidelines for Applying IEC Standards to Electrical Distribution Equipment

Part 9

IEC standards

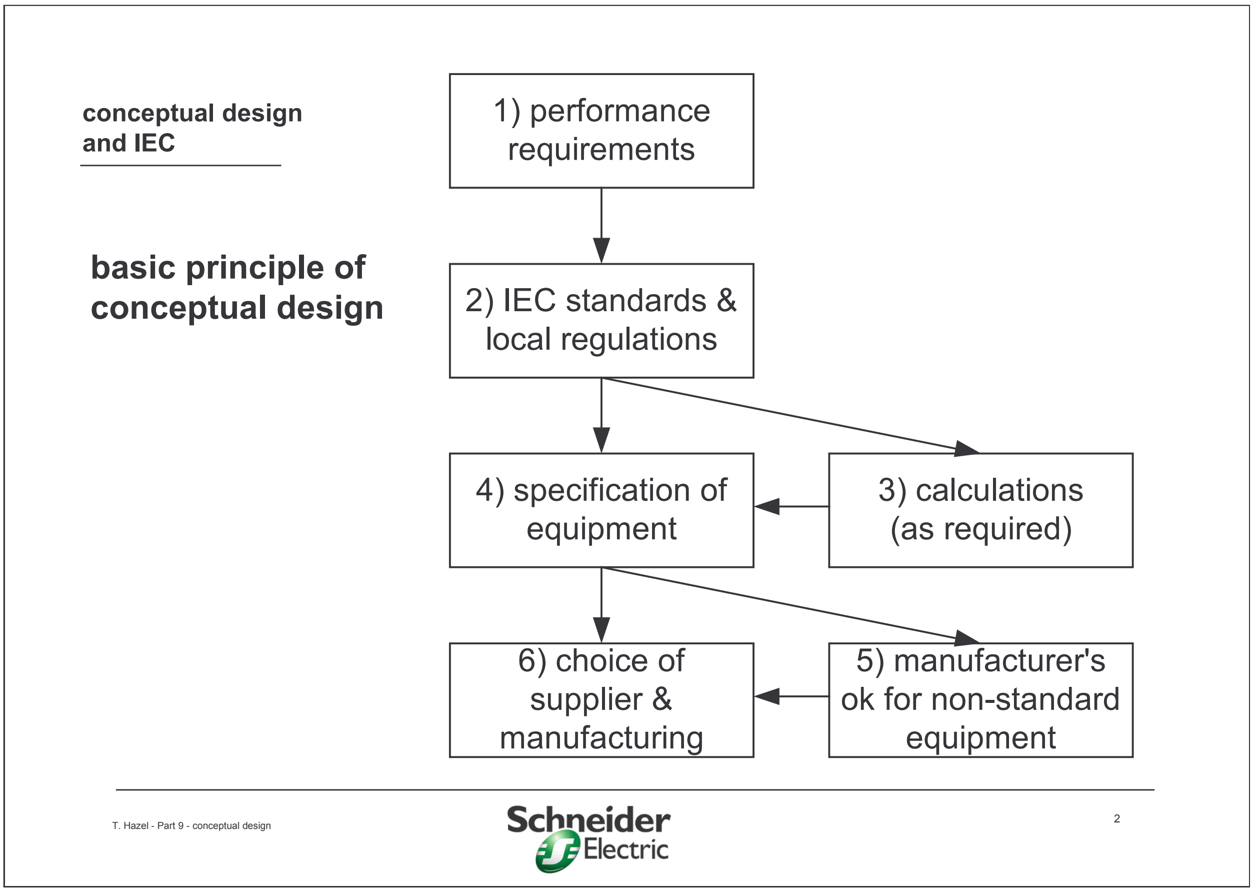
conceptual design

conceptual design

The conceptual design is the most important phase of engineering. The purpose of the conceptual design is to determine the characteristics of the electrical equipment to be purchased in order to meet the performance requirements. This means defining the performance requirements in terms of:

- ☐ power required
- ☐ availability
- ☐ quality of voltage waveform
- ☐ maintenance without interruption
- ☐ etc.

Correct earthing of the electrical installation is a very important part of the conceptual design. The ambient conditions where electrical equipment is installed must also be carefully defined. Good equipment will not perform well if not correctly installed.



conceptual design and IEC

basic principle of conceptual design

1) performance requirements

2) IEC standards & local regulations

3) calculations (as required)

4) specification of equipment

5) manufacturer's ok for non-standard equipment

6) choice of supplier & manufacturing

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1) Performance requirements are dictated by the process that the power system is supplying.

2) Applicable IEC standards and local regulations must be complied with. This covers connection requirements with the local utility. This implies knowing what is in the standards and local regulations.

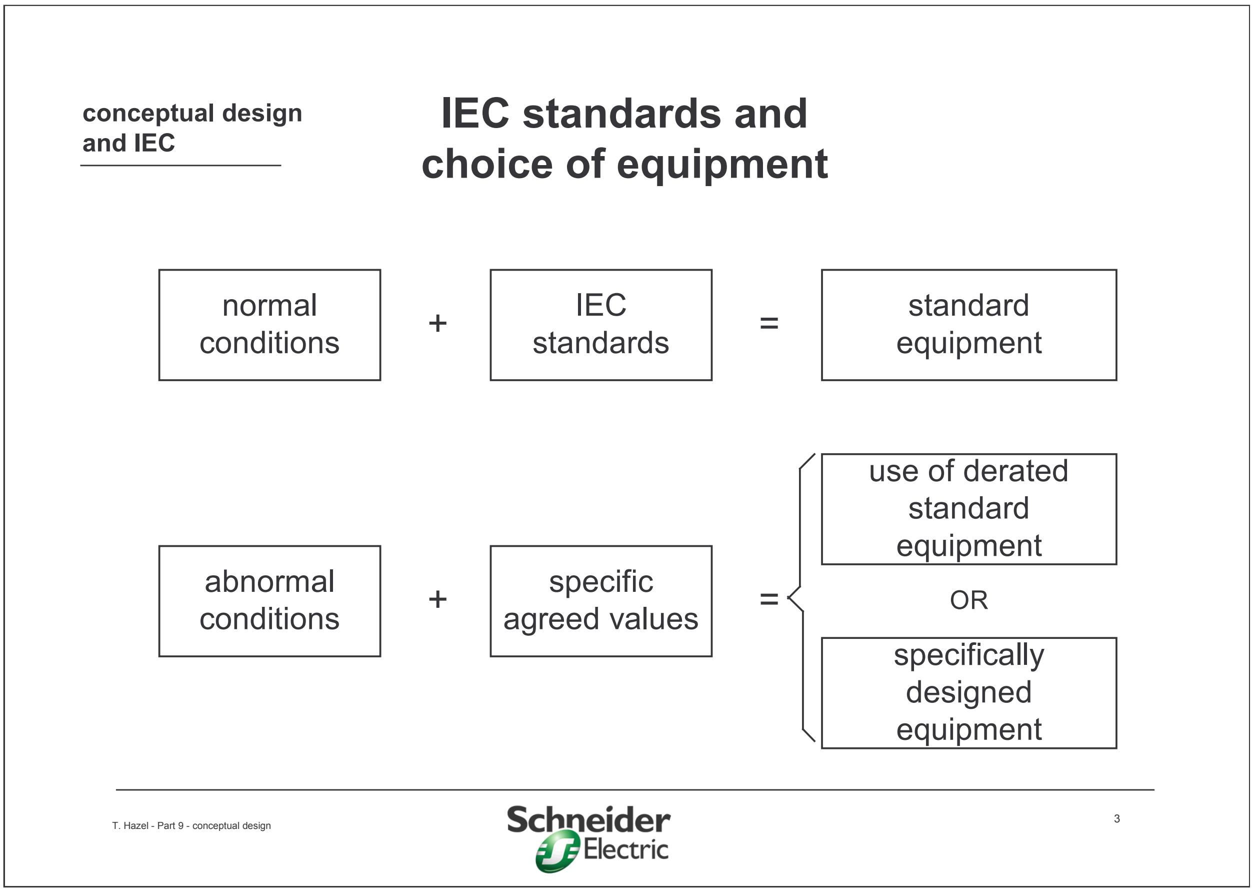
3) Calculations are often required to determine characteristics of equipment. When available, internationally recognized methods should be used. All calculations require verification.

4) Equipment specifications for enquiries must be prepared based on applicable IEC standards and any particular requirements.

5) Manufacturer’s must confirm the suitability of their equipment for the intended purpose, especially if there are requirements not covered by the applicable standards.

6) The final and major step in the conceptual design is deciding that proposed equipment will meet the performance requirements. The performance requirements of critical items of equipment should be included in the purchase specifications to ensure that the manufacturer is aware of the intended use of the equipment.

As in any chain, the weakest link determines the end result. All steps are equally important and should be reviewed during the design phase.



conceptual design and IEC

IEC standards and choice of equipment

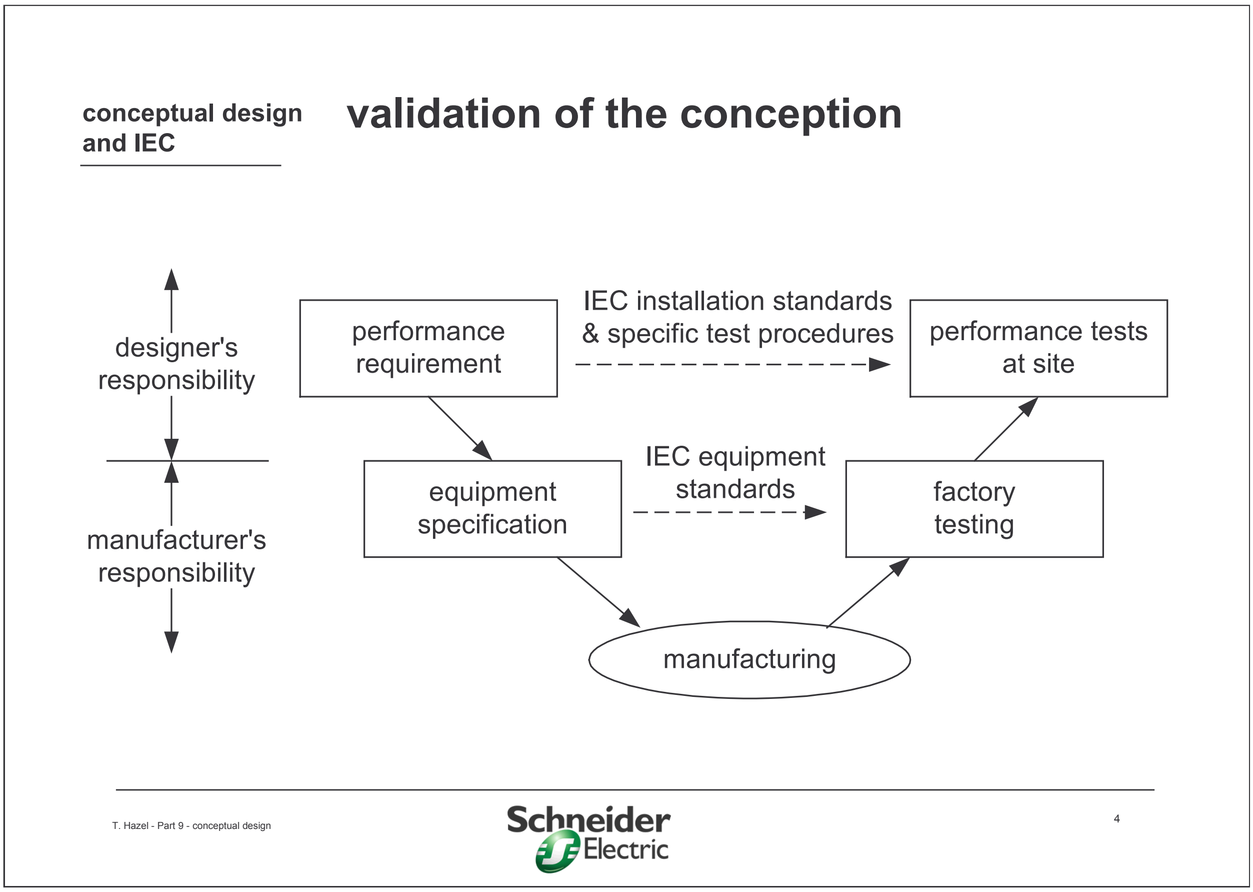
normal conditions + IEC standards = standard equipment

abnormal conditions + specific agreed values = use of derated standard equipment OR specifically designed equipment

The conceptual design is easiest when the conditions in which the electrical equipment will be used correspond to those defined in the applicable IEC standards. Based on the philosophy of IEC, this should be in more than 90% of the cases. When there are non-standard requirements, confirmation must be obtained from the manufacturer.

In order to help engineers choose the correct equipment, many IEC equipment standards have lists of information that should be given with enquiries, tenders, and orders. An example of these lists (taken from the new high-voltage alternating current circuit-breaker standard IEC62271-100) is given in the annex. These lists are not exhaustive however, and should be completed with any application specific requirements such as rough shipping and handling, size and weight limitations, as well as any other information that is important in choosing equipment.

Where possible standard equipment should be chosen. It is easier to maintain standard equipment and obtain spare parts.



conceptual design and IEC

validation of the conception

designer's responsibility

manufacturer's responsibility

performance requirement

IEC installation standards & specific test procedures

performance tests at site

equipment specification

IEC equipment standards

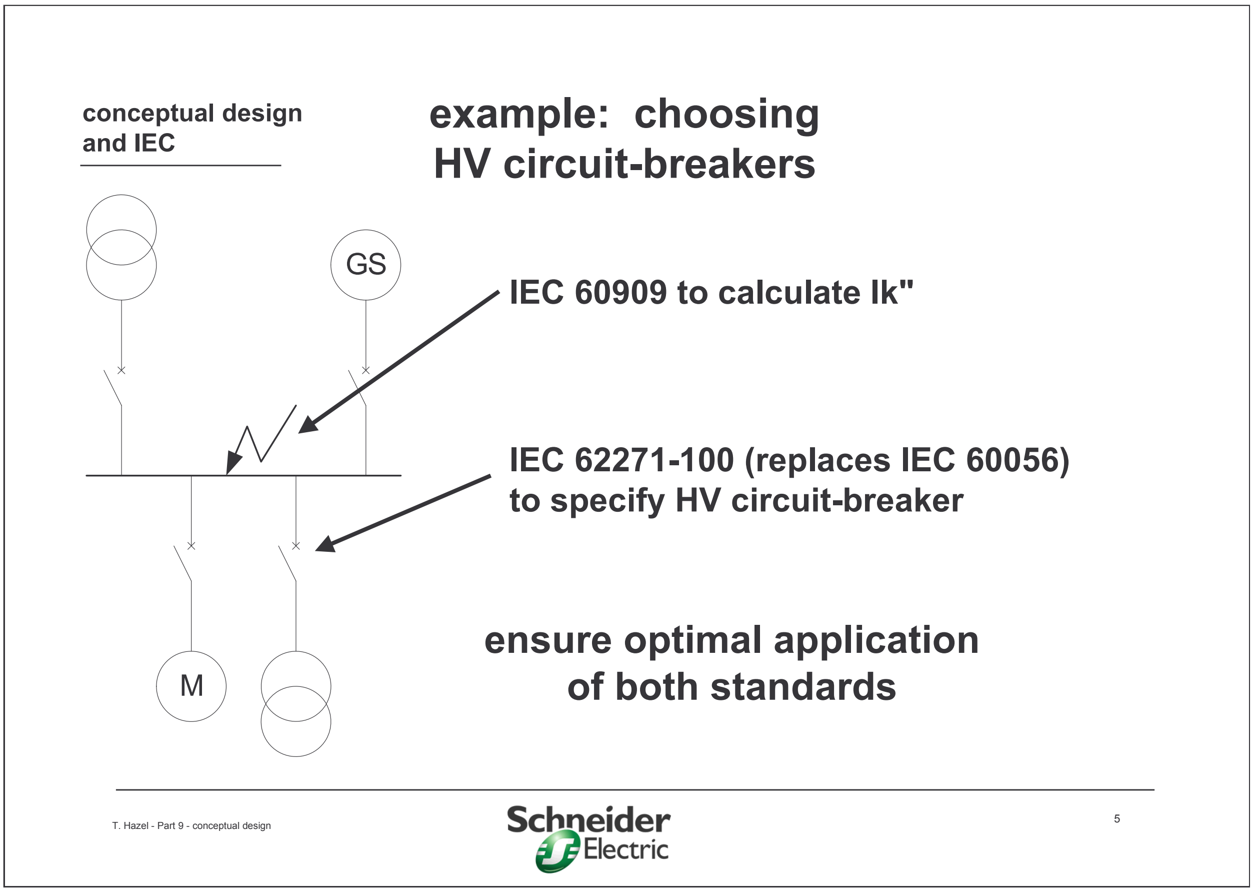
factory testing

manufacturing

Equipment is tested at the factory to demonstrate compliance with the specifications. It is only at the site that the complete electrical installation can be tested to determine if the performance requirements are met. Generally this is the responsibility of the engineers who performed the conceptual design.

The manufacturer is responsible for performance at site only when he has determined the equipment required. This is often the case for harmonic filters where the characteristics of the components are determined by the manufacturer based on a general specification and harmonic performance requirements. It is the responsibility of the conceptual design to specify the performance criteria and provide the necessary data.

The IEC equipment standards contain the information necessary for factory testing. IEC installation standards include some information regarding tests to be done at site. This is normally insufficient for demonstrating fulfillment of the performance requirements. The tests to be performed at site should be included in the conceptual design. Since these tests may influence the design of equipment (special sensors etc.) they should be listed in purchase specifications.



conceptual design
and IEC

example: choosing HV circuit-breakers

IEC 60909 to calculate Ik"

IEC 62271-100 (replaces IEC 60056) to specify HV circuit-breaker

ensure optimal application of both standards

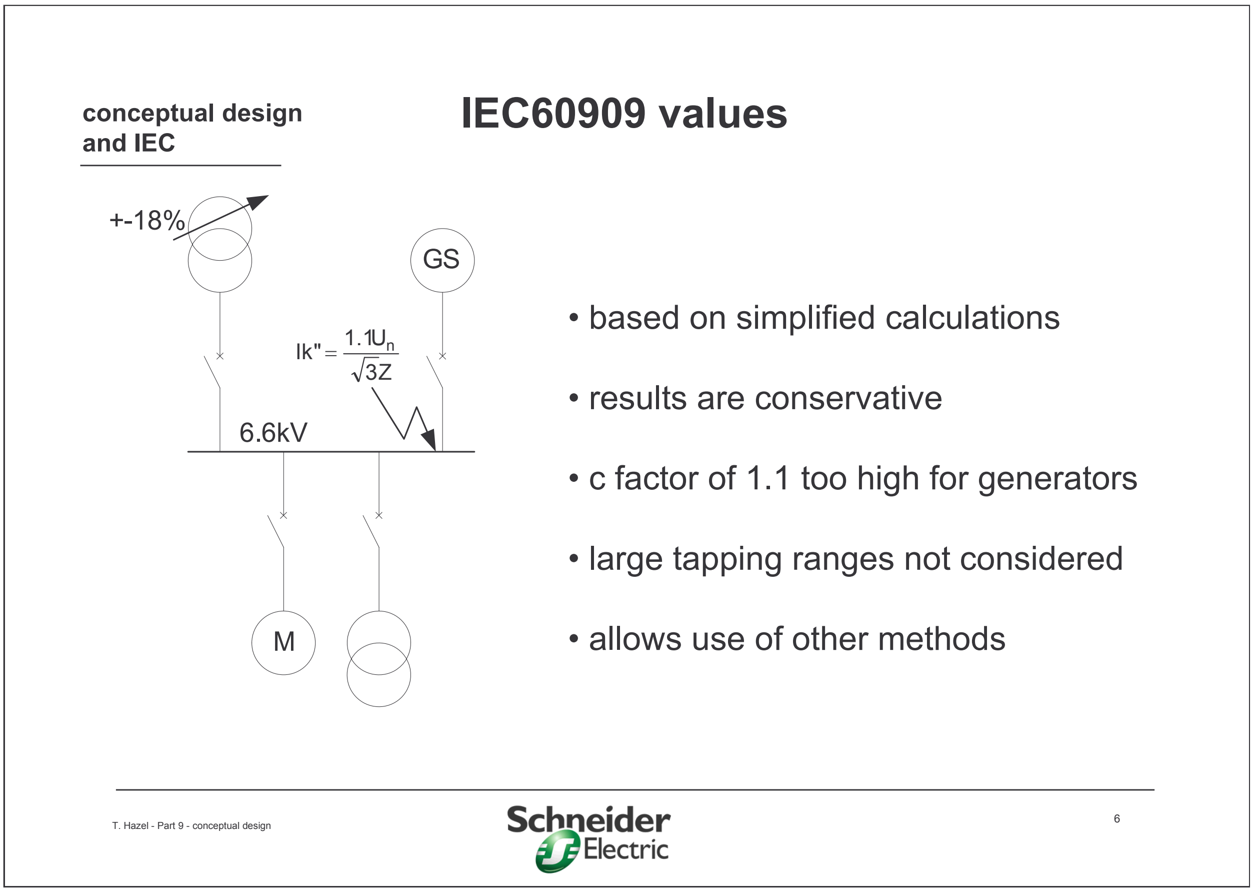
An example of a conceptual design which sometimes does not correspond with the IEC standards is the choice of high-voltage circuit-breakers in industrial applications where large generators are used.

Two different IEC standards are used in this design:

☐ IEC60909 for calculating the short-circuit current

☐ IEC62271-100 for selecting, manufacturing, and testing the circuit-breaker.

Both of these standards however, have limitations that must be reviewed during the conceptual design.



+-18%
GS
$Ik'' = \frac{1.1U_n}{\sqrt{3}Z}$
6.6kV
M

conceptual design
and IEC

IEC60909 values

- based on simplified calculations
- results are conservative
- c factor of 1.1 too high for generators
- large tapping ranges not considered
- allows use of other methods

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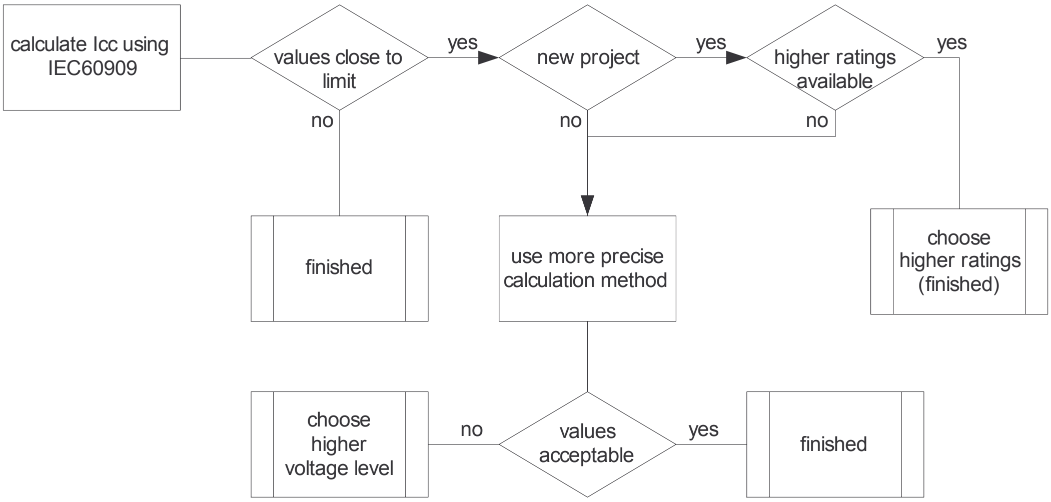
IEC60909 describes a method that can be used for calculating short-circuit currents. The method is simple and well adapted for hand calculations as well as calculations done by computers. The method generally gives conservative values since a correction factor is applied. The value of this factor “c” depends on the voltage level and also if one is determining the maximum or minimum short-circuit current.

For some industrial applications the results are too conservative. This could sometimes mean having to choose a higher voltage level with the associated extra cost. Since the IEC standard does not exclude the use of other, more precise calculation methods, the engineer responsible for the conceptual design must determine if it is reasonable to use another method or if other gear is required.

suggested procedure



calculate Icc using IEC60909

values close to limit

yes

new project

yes

higher ratings available

yes

no

no

no

finished

use more precise calculation method

choose higher ratings (finished)

choose higher voltage level

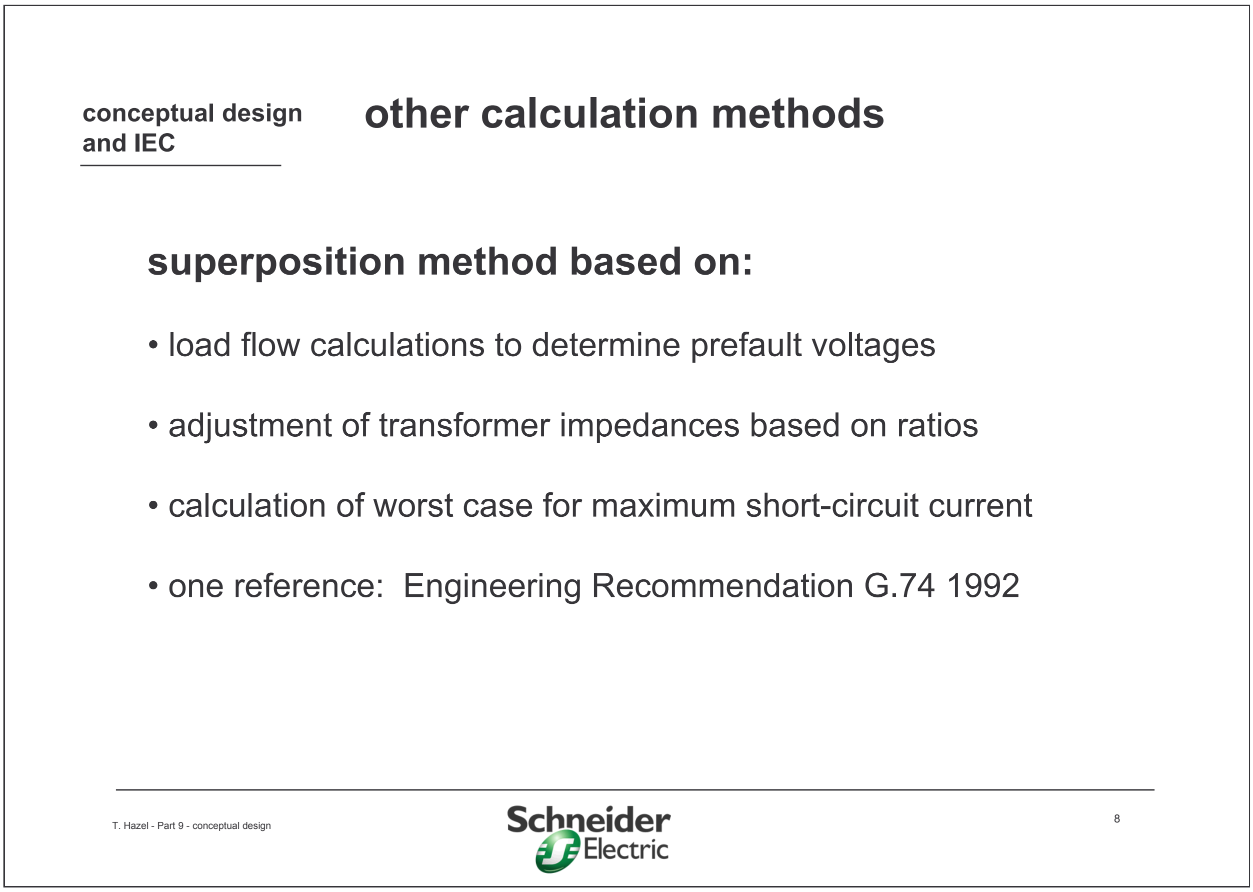
no

values acceptable

yes

finished

The flow chart describes how the choice of the method to use can be made. Where possible the IEC standard should be used since it simplified the design procedure and does not require special approval. Normally justification for using a method which is not standardized is required, and it can take a long time.

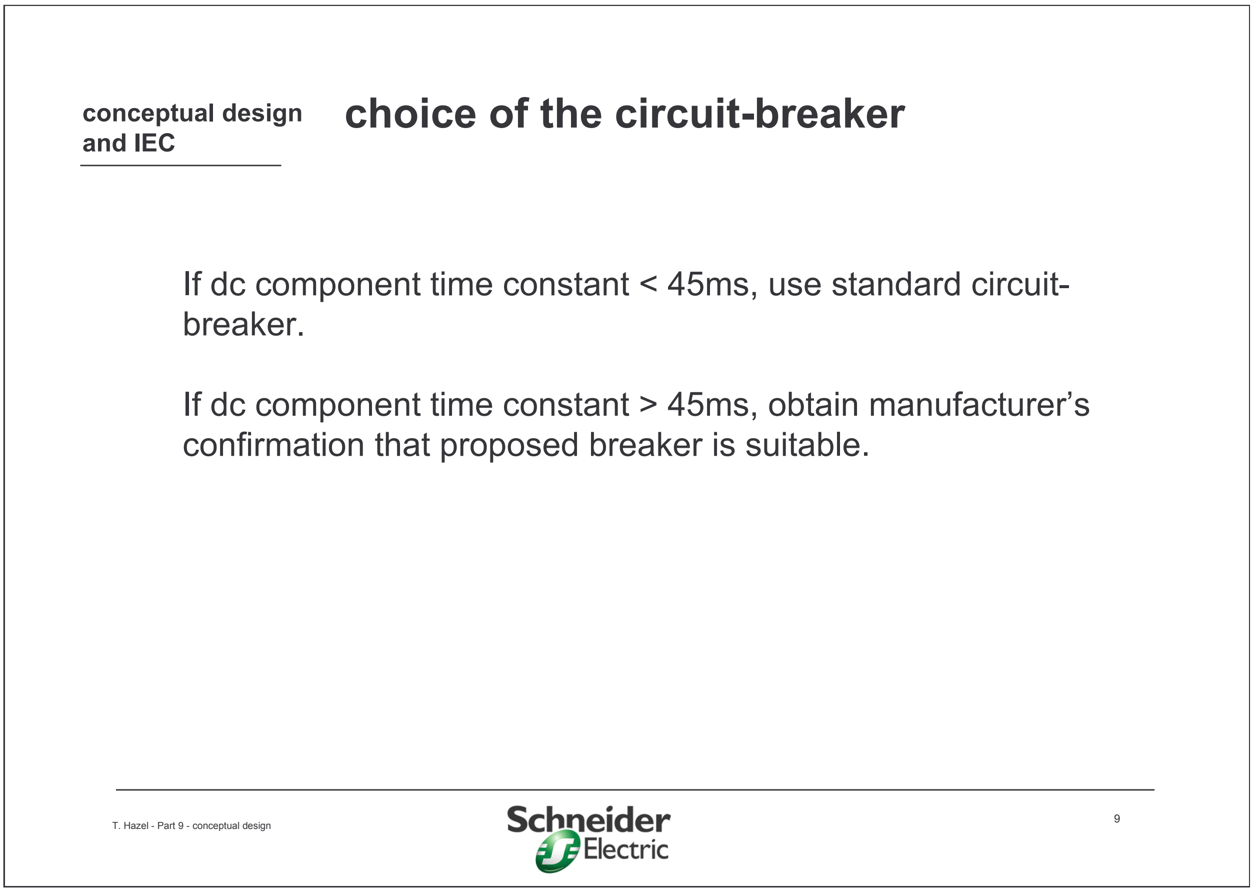


other calculation methods

superposition method based on:

- load flow calculations to determine prefault voltages
- adjustment of transformer impedances based on ratios
- calculation of worst case for maximum short-circuit current
- one reference: Engineering Recommendation G.74 1992

The superposition method is often used when it has been determined that IEC60909 is too conservative.



conceptual design and IEC

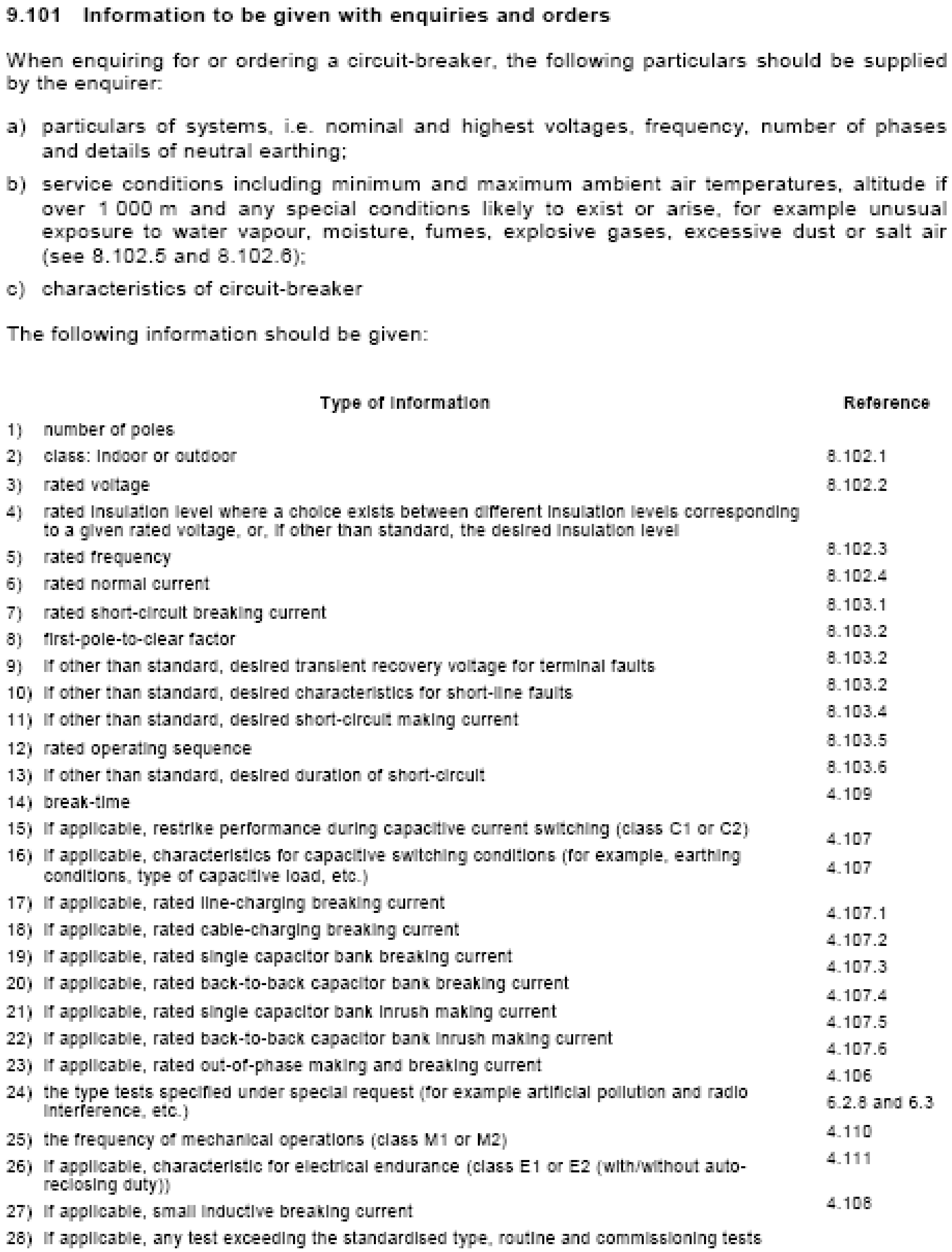
choice of the circuit-breaker

If dc component time constant < 45ms, use standard circuit-breaker.

If dc component time constant > 45ms, obtain manufacturer’s confirmation that proposed breaker is suitable.

The subject of the choice of high-voltage circuit-breakers based on the new IEC standard 62271-100 is covered in part 5 of the tutorial. It is not necessary that short-circuit current characteristics be determined by using IEC60909 when choosing a circuit-breaker according to this standard.

Example of information to be given with enquiries 1/3



9.101 Information to be given with enquiries and orders

When enquiring for or ordering a circuit-breaker, the following particulars should be supplied by the enquirer:

a) particulars of systems, i.e. nominal and highest voltages, frequency, number of phases and details of neutral earthing;

b) service conditions including minimum and maximum ambient air temperatures, altitude if over 1 000 m and any special conditions likely to exist or arise, for example unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 8.102.5 and 8.102.6);

c) characteristics of circuit-breaker

The following information should be given:

	Type of information	Reference
1)	number of poles	
2)	class: indoor or outdoor	8.102.1
3)	rated voltage	8.102.2
4)	rated insulation level where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, the desired insulation level	
5)	rated frequency	8.102.3
6)	rated normal current	8.102.4
7)	rated short-circuit breaking current	8.103.1
8)	first-pole-to-clear factor	8.103.2
9)	if other than standard, desired transient recovery voltage for terminal faults	8.103.2
10)	if other than standard, desired characteristics for short-line faults	8.103.2
11)	if other than standard, desired short-circuit making current	8.103.4
12)	rated operating sequence	8.103.5
13)	if other than standard, desired duration of short-circuit	8.103.6
14)	break-time	4.109
15)	if applicable, restrike performance during capacitive current switching (class C1 or C2)	4.107
16)	if applicable, characteristics for capacitive switching conditions (for example, earthing conditions, type of capacitive load, etc.)	4.107
17)	if applicable, rated line-charging breaking current	4.107.1
18)	if applicable, rated cable-charging breaking current	4.107.2
19)	if applicable, rated single capacitor bank breaking current	4.107.3
20)	if applicable, rated back-to-back capacitor bank breaking current	4.107.4
21)	if applicable, rated single capacitor bank inrush making current	4.107.5
22)	if applicable, rated back-to-back capacitor bank inrush making current	4.107.6
23)	if applicable, rated out-of-phase making and breaking current	4.106
24)	the type tests specified under special request (for example artificial pollution and radio interference, etc.)	6.2.8 and 6.3
25)	the frequency of mechanical operations (class M1 or M2)	4.110
26)	if applicable, characteristic for electrical endurance (class E1 or E2 (with/without auto-reclosing duty))	4.111
27)	if applicable, small inductive breaking current	4.108
28)	if applicable, any test exceeding the standardised type, routine and commissioning tests	

Example of information to be given with enquiries 2/3

d) characteristics of the operating mechanism of circuit-breaker and associated equipment, in particular:
   1) method of operation, whether manual or power;
   2) number and type of spare auxiliary switches;
   3) rated supply voltage and rated supply frequency;
   4) number of releases for tripping, if more than one;
   5) number of releases for closing, if more than one.

e) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels.

NOTE The enquirer should give information of any special conditions not included above, that might influence the tender or order (see also the note in 8.101).

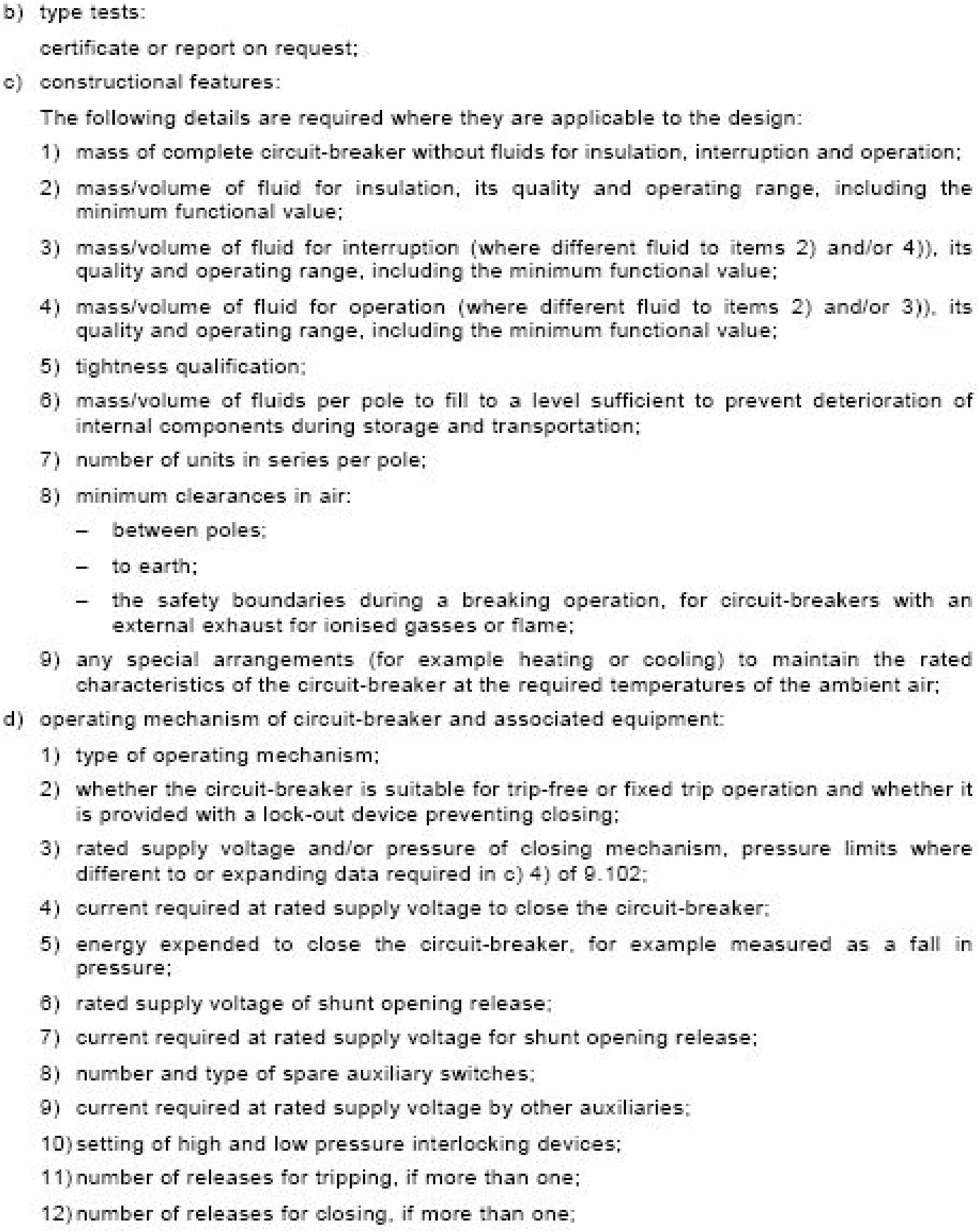
9.102 Information to be given with tenders

When the enquirer requests technical particulars of a circuit-breaker, the following information (those which are applicable) should be given by the manufacturer, with the descriptive matter and drawings:

a) rated values and characteristics:

	Type of information	Reference
1)	number of poles	
2)	class: indoor or outdoor, temperature, ice-coating	8.102.5
3)	rated voltage	8.102.1
4)	rated insulation level	8.102.2
5)	rated frequency	8.102.3
6)	rated normal current	8.102.4
7)	rated short-circuit breaking current	8.103.1
8)	first-pole-to-clear factor	8.103.2
9)	transient recovery voltage for terminal faults	8.103.2
10)	characteristics for short-line faults	8.103.2
11)	rated short-circuit making current	8.103.4
12)	rated operating sequence	8.103.5
13)	rated duration of short-circuit	8.103.6
14)	rated opening time, rated break-time and rated closing time	4.109
15)	restrike performance during capacitive current switching (Class C1 or C2)	4.107
16)	characteristics for capacitive current switching conditions	4.107
17)	rated line-charging breaking current	4.107.1
18)	rated cable-charging breaking current	4.107.2
19)	rated single capacitor bank breaking current	4.107.3
20)	rated back-to-back capacitor bank breaking current	4.107.4
21)	rated single capacitor bank inrush making current	4.107.5
22)	rated back-to-back capacitor bank inrush making current	4.107.6
23)	rated out-of-phase making and breaking current	4.106
24)	the type tests specified under special request (for example artificial pollution and radio interference, etc.)	6.2.8 and 6.3
25)	class M1 or class M2 for mechanical endurance	4.110
26)	class E1 or class E2 (with/without auto-reclose) for electrical endurance	4.111
27)	small inductive breaking current	4.108

Example of information to be given with enquiries 3/3



b) type tests:

certificate or report on request;

c) constructional features:

The following details are required where they are applicable to the design:

1) mass of complete circuit-breaker without fluids for insulation, interruption and operation;
2) mass/volume of fluid for insulation, its quality and operating range, including the minimum functional value;
3) mass/volume of fluid for interruption (where different fluid to items 2) and/or 4)), its quality and operating range, including the minimum functional value;
4) mass/volume of fluid for operation (where different fluid to items 2) and/or 3)), its quality and operating range, including the minimum functional value;
5) tightness qualification;
6) mass/volume of fluids per pole to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
7) number of units in series per pole;
8) minimum clearances in air:
   - between poles;
   - to earth;
   - the safety boundaries during a breaking operation, for circuit-breakers with an external exhaust for ionised gasses or flame;
9) any special arrangements (for example heating or cooling) to maintain the rated characteristics of the circuit-breaker at the required temperatures of the ambient air;

d) operating mechanism of circuit-breaker and associated equipment:

1) type of operating mechanism;
2) whether the circuit-breaker is suitable for trip-free or fixed trip operation and whether it is provided with a lock-out device preventing closing;
3) rated supply voltage and/or pressure of closing mechanism, pressure limits where different to or expanding data required in c) 4) of 9.102;
4) current required at rated supply voltage to close the circuit-breaker;
5) energy expended to close the circuit-breaker, for example measured as a fall in pressure;
6) rated supply voltage of shunt opening release;
7) current required at rated supply voltage for shunt opening release;
8) number and type of spare auxiliary switches;
9) current required at rated supply voltage by other auxiliaries;
10) setting of high and low pressure interlocking devices;
11) number of releases for tripping, if more than one;
12) number of releases for closing, if more than one;